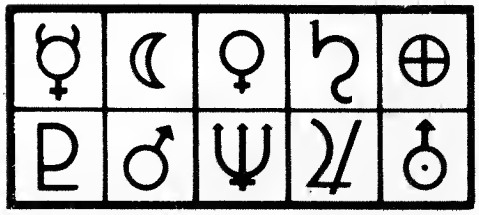

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June 1967

THE MICROBIAL PROFILE OF A VERTICAL LAMINAR AIRFLOW SURGICAL THEATER

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SANDIA CORPORATION

PRIME CONTRACTOR TO THE U.S. ATOMIC ENERGY COMMISSION | ALBUQUERQUE, NEW MEXICO; LIVERMORE, CALIFORNIA; TONOPAH, NEVADA

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by

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ABSTRACT

This report describes a quantitative and qualitative microbiological study conducted in a vertical laminar airflow surgical theater. Air samples were collected within the room and also directly at the incision. The levels of airborne viable particles that were detected and the types of microorganisms that were isolated are described. Data for a similar study in a conventional surgical theater are also presented.

It would appear that the laminar airflow surgical theater has a very low level of airborne microbial contamination, especially at the wound site. Higher levels of airborne viable contamination were detected in the conventional surgical theater.

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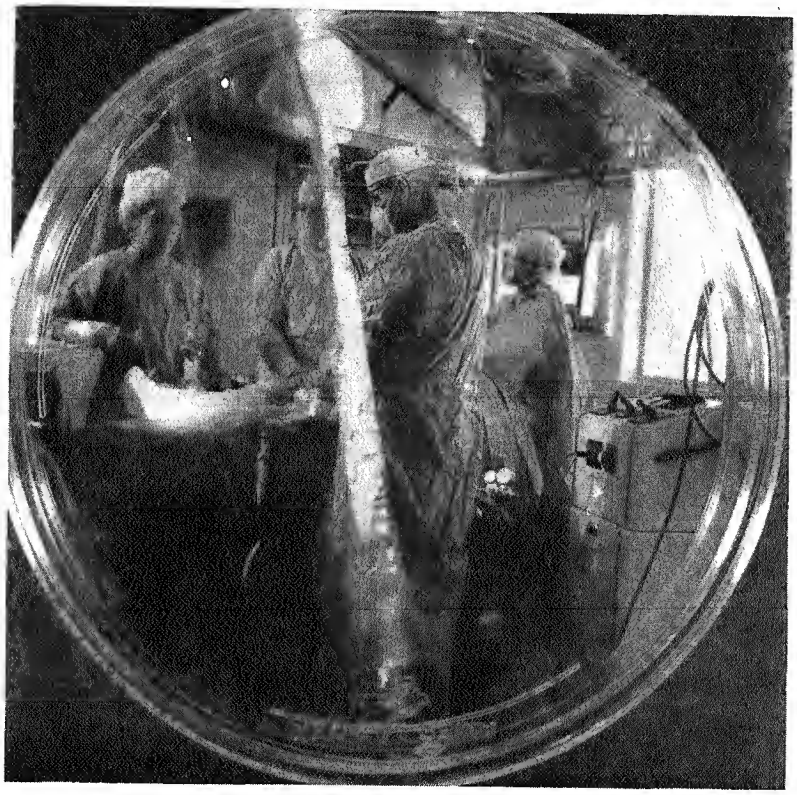

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I. INTRODUCTION

Post-operative infections have been a continuing problem for hospitals for the past decade. A number of microbiological surveys have been conducted to determine the microbial profile of institutional environments and to establish methods for controlling microbial contamination within hospitals[1-9]. More recently, the National Aeronautics and Space Administration (NASA) has recognized and established a requirement for controlling both viable (microbial) and nonviable (dust, lint, fibers, etc.) contamination on its planetary orbiting and landing space hardware[10-13]. Both the hospital surveys and other studies in the NASA program[14-18] directed toward determining the microbial profile of clean rooms and spacecraft assembly areas have shown that fairly large numbers of microorganisms can and do exist on surfaces and in the air of intramural environments. However, thorough housekeeping practices and other control measures can and do reduce the level of microbial contamination within a given environment.

One of the most recent advances in the control of airborne contamination is use of the laminar airflow principle developed by Whitfield[19] to achieve a "clean environment". In Federal Standard No. 209a[20] laminar airflow is defined as, "airflow in which the entire body of air within a confined area moves with uniform velocity along parallel lines".

Several preliminary studies have been conducted in the laminar airflow surgery[21-23]. However, the present study was initiated to provide both a quantitative and a qualitative estimate of the microbial contamination present within a conventional surgery and within a vertical laminar airflow surgery. The rooms surveyed are mirror images and both are subjected to the same maintenance and housekeeping practices. Surgical procedures and practices

are the same in both rooms. The only difference is the filtration and movement of air within the respective rooms. Thus, it was thought that the influence of laminar airflow on the control of airborne microbial contamination might well be evaluated under this type of situation.

II. SURGICAL THEATERS INCLUDED IN THIS STUDY

A. Vertical Laminar Airflow Surgery

The vertical laminar airflow surgery was developed by adding a complete air conditioning unit to the full ceiling area of an 18 by 16 foot operating room (Figure 1). This air conditioning unit contained a filter bank of high efficiency particulate air (HEPA) filters. The entire depth of the air conditioning unit with filters was 2.5 feet. Yet, the ceiling height below the filters remained a workable 8.5 feet height. Clear vinyl curtains extended on all four sides of the enclosure from the ceiling to near the floor (ca. 24-30 in. from the floor). The work area inside the vinyl curtains remained 10 by 12 feet, providing a dual purpose traffic aisle-air return passage 3 feet wide outside the periphery of the curtained area.

Figure 2 presents a picture of the interior of the completed room. As shown in Figure 2, the plastic curtains are divided into halves along each side of the room and can be drawn to each corner for ease of entry of the patient and equipment into the room. Then, each half of the curtain along each side of the room is drawn together and sealed in the center with Velcro V-Lok tape[(a)]. This completes the curtained area around the room and provides ceiling to floor laminar airflow.

[(a)] Commercial names are used throughout the report for identification only and their mention does not constitute endorsement by the authors.

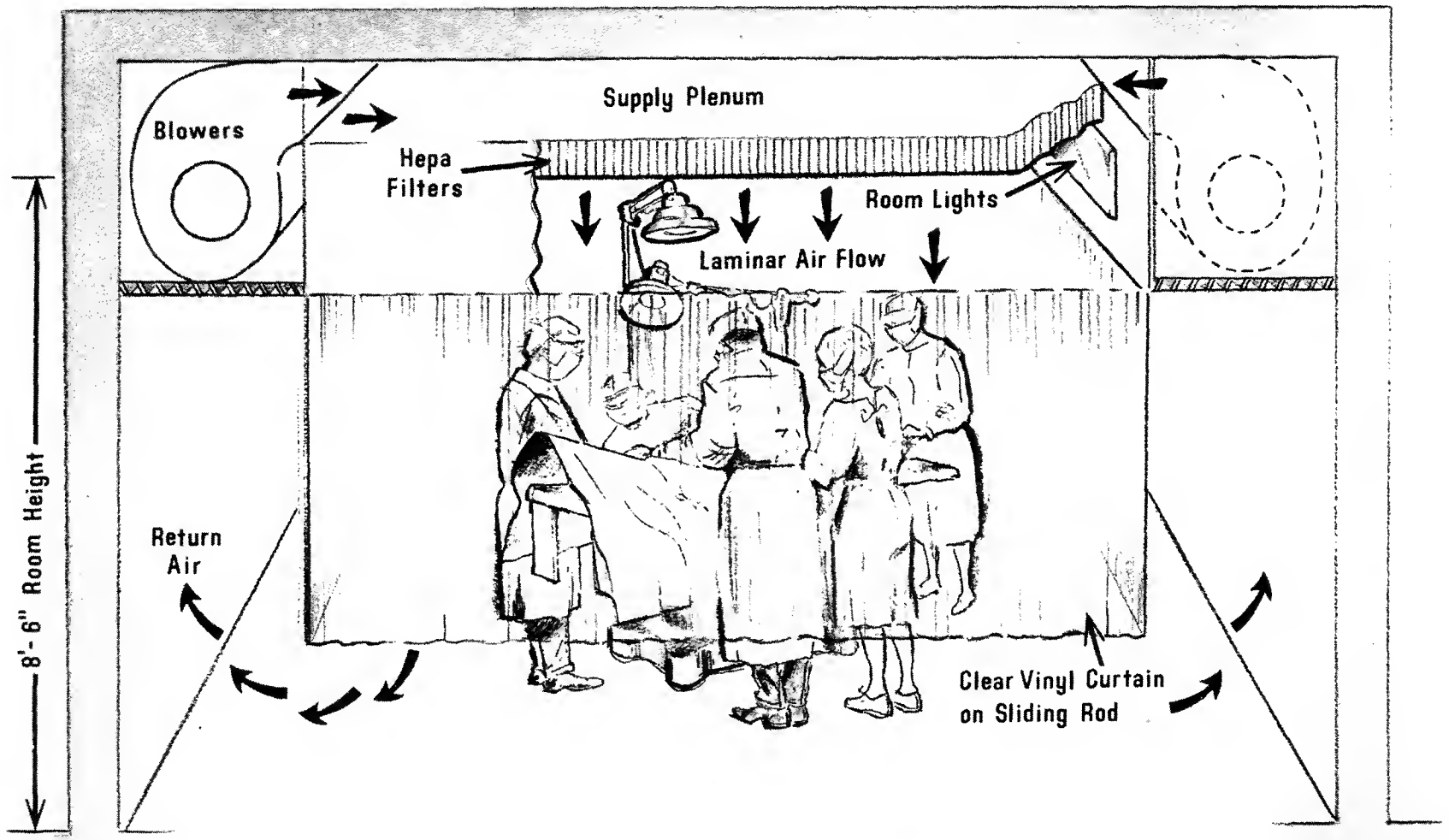

Figure 1. Schematic drawing of the laminar airflow surgery. Air leaves HEPA filters as laminar airflow, passing down over the operative field and then under and around the vinyl curtains to the return air passage around the room.

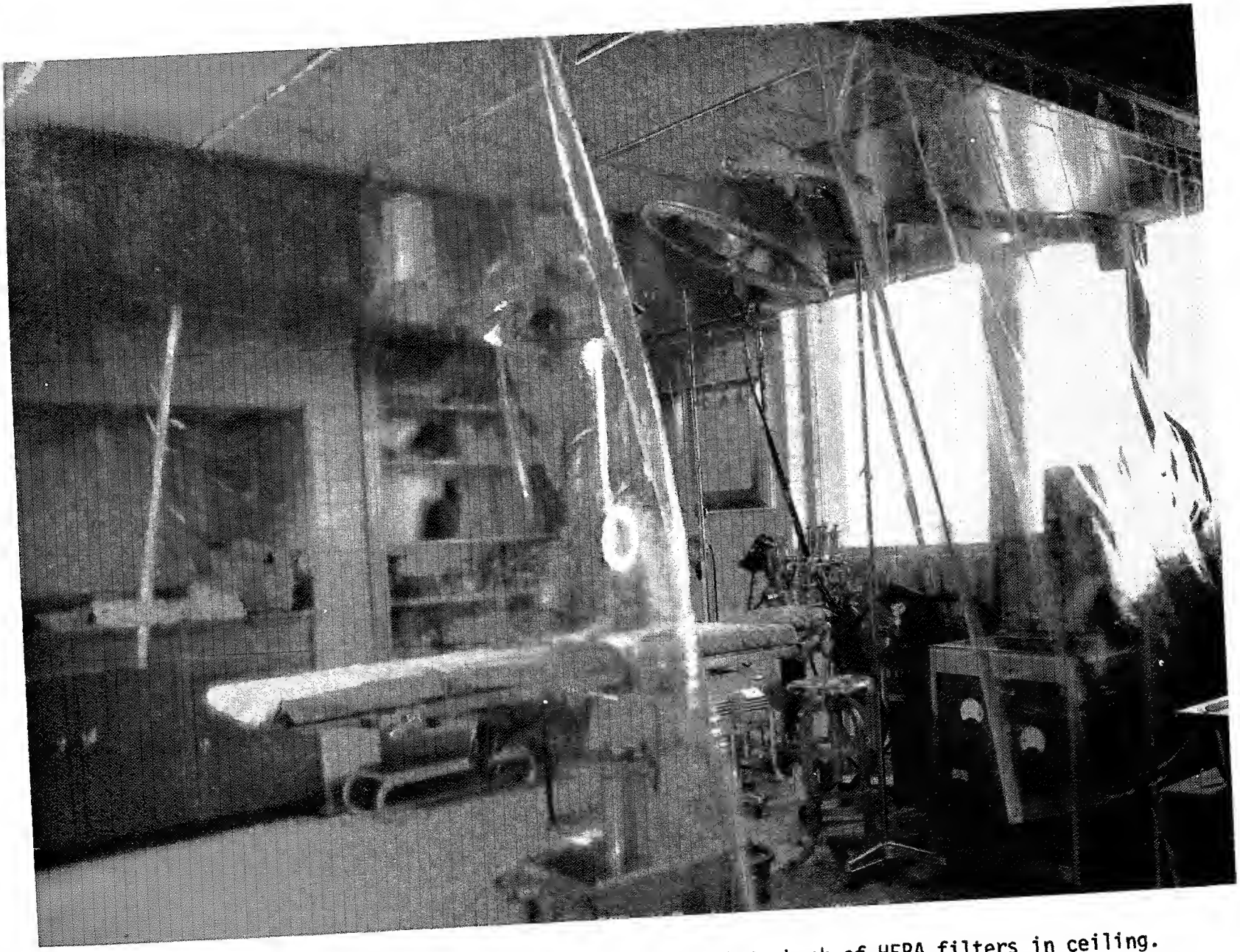

Figure 2. Interior view of the laminar airflow surgery. Note bank of HEPA filters in ceiling. Also, vinyl curtains in background sealed whereas those in foreground remain open for entry into room prior to start of surgery.

Six blowers are located near the ceiling and draw the return air from the floor area up the return air passages outside the curtained area. The return air then passes through coarse, woven Dacron[a] prefilters and is forced into the supply plenum. This air then passes through the HEPA filters that remove 99.97 percent of all particles 0.3 microns or larger. Air leaving the filter flows uniformly downward inside the curtained area, diluting and removing airborne contamination. Such laminar airflow provides ten changes of air each minute in the operating area with a moving velocity of only one mile per hour (100 feet per minute, 600 changes of air per hour). An auxiliary air conditioning unit located on the roof adds new or make-up air via the supply plenum at the rate of 1,000 $ft.^3$ per minute.

Pneumatic controls are mounted on one wall in the return air passage and regulate the temperature to 68F ($\pm$ 2F) and the relative humidity to 55 per cent ($\pm$ 5 percent). This temperature and relative humidity have been maintained and also found to be comfortable.

Six incandescent lamps for general lighting are located high on the walls near the ceiling filter bank to avoid interference with the airflow. The large, round operating lights commonly fixed to the ceiling over the operating table and the operative field interfere with the laminar downward airflow and produce a very undesirable turbulence between their under surface and the operative field. Presently, special small operating lights are being developed and tested.

B. Conventional (nonlaminar) Surgery

Operating room (OR) No. 2 is a conventional-type surgery and is a mirror image (16 by 18 feet) of OR No. 1, the converted vertical laminar

[a]Commercial names are used throughout the report for identification only and their mention does not constitute endorsement by the authors.

airflow surgery. In OR No. 2 air enters the room through inlets near the ceiling and this air is removed through exhaust grills along the floor. The number of air changes per hour in OR No. 2 is approximately 17 as contrasted to some 600 changes per hour in OR No. 1. Routine housekeeping procedures are the same in both OR No. 1 and 2. Thus, the only differences in these operating rooms is the filtered laminar airflow principle employed in OR No. 1.

III. MICROBIOLOGICAL SAMPLING PROCEDURES

A. Air Sampling Techniques

Volumetric air samples were collected with Reyniers[(a)] slit samplers. Samplers were equipped with one-hour clock motors and each sampler was operated at a sampling velocity of one cubic foot of air per minute. For studies at the wound site, Pyrex[(a)] glass probes, 2.5 to 3.0 inches long, 1/4 in. in diameter, were inserted into surgical tubing 24 - to 30-in. long. The other end of the surgical tubing was connected to a hole drilled into a number 10 rubber stopped by means of a piece of Pyrex glass tubing (Figure 3). The entire probe assembly was sterilized prior to use. Trypticase soy agar[(a)] was used as the collecting and incubation medium. All samples were incubated at 37 C. for 72 hours and then at room temperature for an additional 72 hours.

B. Air Sampling Sites

Since maximum turbulence might be expected underneath the OR table, one Reyniers sampler was placed on the floor at the foot of the OR table and a second sampler was placed on the floor at the head of the OR table. Both samplers were underneath the table approximately 6 in. from the respective

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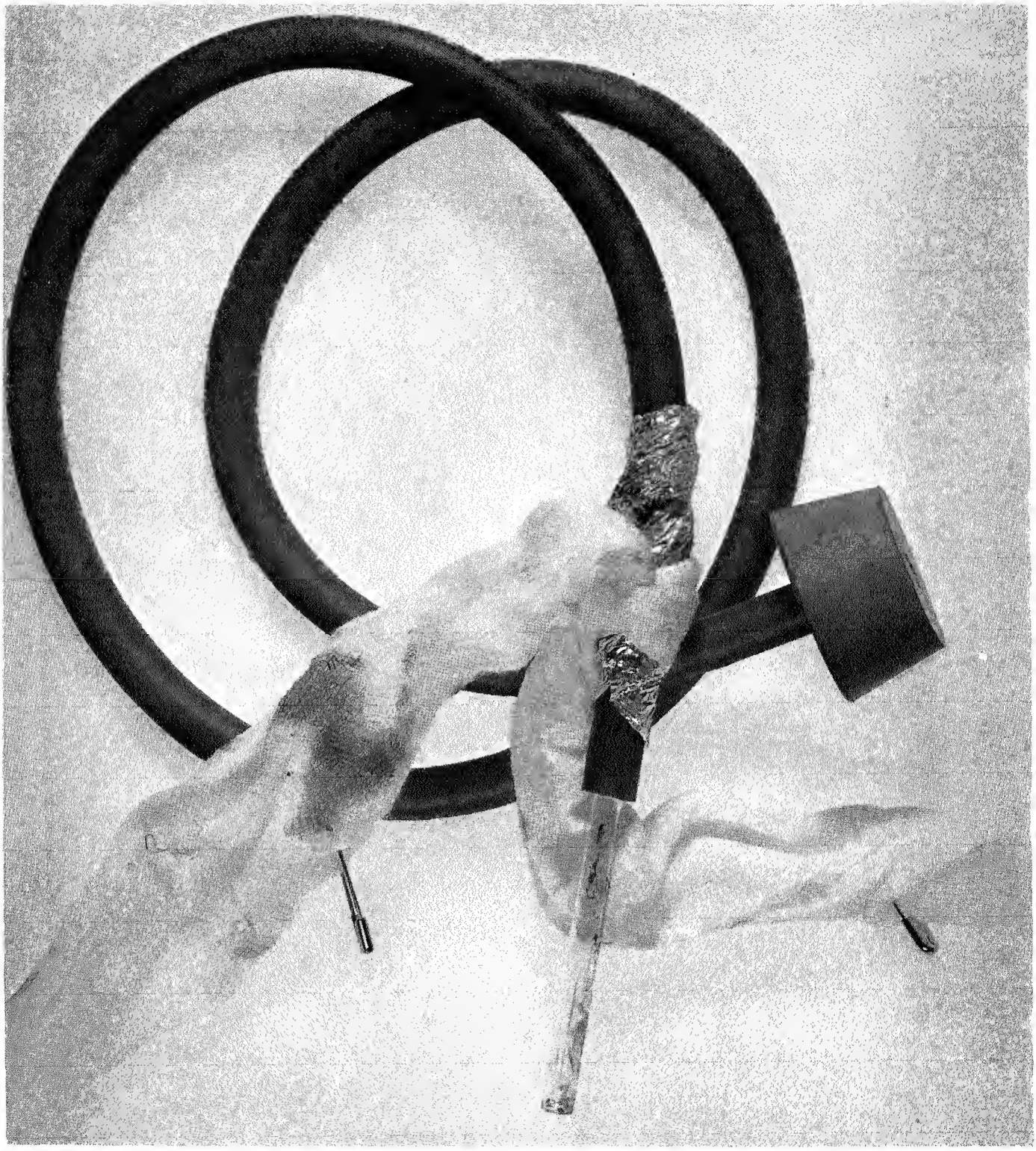

Figure 3. Sampling probe after use at wound site.

ends of the OR table. Two other Reyniers samplers were placed, one each, on either side of the OR table at a height of ca. 30 in. Sample collection began before the OR was occupied and continued through the pre-operative preparations, the surgical procedure and until the post-operative clean-up. The sterile probes were placed at the wound site at the time the incision was made. Prior to this time, the samplers were placed in close proximity to the operative field and samples were collected with probes in place near the operative field. Sterile probes were placed at the wound site when the incision was made.

C. Identification of Microorganisms

The minimum test set procedure of Rypka, et.al., was used to identify the microorganisms recovered. Complete details of this procedure have been described earlier[24].

IV. RESULTS AND DISCUSSION

Figure 4 contains the results of air sampling studies conducted in the laminar airflow surgery during an aortic bifurcation resection. Fluctuations in the number of airborne viable particles can be related with personnel activity and may be seen in samples collected with the sampler on the floor when the room was not in a laminar flow configuration. However, when the vinyl curtains were sealed and laminar airflow was established, the numbers of airborne viable contamination dropped rapidly and ranged from 0 to about 0.2 of a viable particle per cubic foot of air. Over 100 cubic feet of air were sampled at the wound site yet only two coagulase negative staphylococci were recovered. The probe was in such close proximity to the wound site that frequently small droplets of blood were deposited on the plate of Trypticase soy agar medium in the Reyniers sampler.

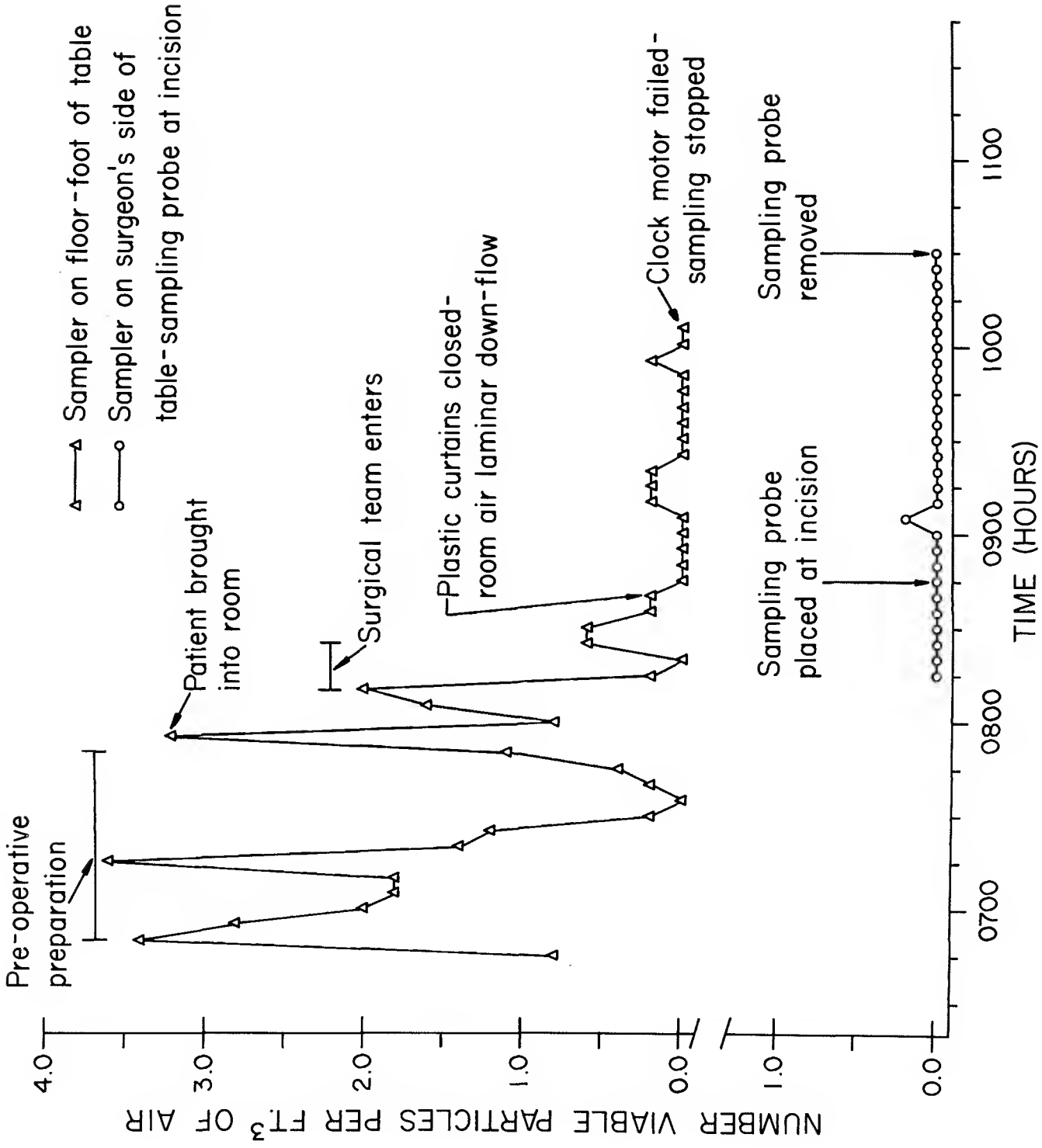

Figure 4. Air Sampling Studies Conducted in the Laminar Airflow Surgery During an Aortic Bifurcation Resection.

Table one contains a qualitative breakdown of the numbers of microorganisms identified after isolation. From this table it can be seen that the largest percentage of microorganisms recovered from the floor and at the wound site were those common to the skin, hair and respiratory tract of humans (Gram-positive cocci and Gram-positive nonsporeforming rods).

Figures five and six contain air sampling results from two other operations in the laminar airflow surgery, a pleural biopsy on the right (Figure 5) and removal of spurs (patient No. 1) and a spinal fusion (patient No. 2) both contained in Figure 6.

Again, there was a correlation of airborne viable particles with personnel activity. In Figure 5 the level of airborne viable particles fluctuated from 0.0 to 8.5 per cubic foot of air until the vinyl curtains were sealed to establish laminar airflow in the OR. At this time, the level of airborne viable particles per cubic foot of air dropped to a low level (0.0- to -less than 1.0) and remained there until the vinyl curtains were parted to remove the patient and begin the post-operative clean-up. Then an increase in the number of airborne viable particles was again detected. It should be noted (Figure 5) that no viable particles were recovered during the period that the sampling probes were at the incision.

Figure six contains essentially the same data, although the plastic curtain seal was broken quite frequently during the spinal fusion procedure. At one point the curtain on one side of the room was open for approximately 15 minutes. However, during the same 110 minutes the probes were in place at the incision (sampling a total of about 220 cubic feet of air) a total of only 6 viable particles (coagulase negative staphylococci) were recovered.

Tables two and three contain the qualitative results of the organisms recovered during air sampling studies done during the pleural biopsy, spur

Table 1

Types of Microorganisms Recovered From the Air During an Aortic Bifurcation Resection in the Vertical Laminar Airflow Operating Room

Type of Microorganism	Percent of Microorganisms	
	Site No. 1, Floor Foot of OR Table[a]	Site No. 2, Probe at Surgeon's side of OR table
	(140/149)[b]	(2/2)
Staphylococcus spp.		
Coagulase +	0.0	0.0
Coagulase -	30.7	100.0
Micrococcus spp.	42.1	0.0
Streptococcus spp.	2.9	0.0
Bacillus spp.	2.1	0.0
Miscellaneous Gram-positive rods[c]	15.0	0.0
Gram-negative rods	4.3	0.0
Molds	2.9	0.0

[a] Volume of air sampled: site No. 1, (200 ft.^{3}); site No. 2, (110 ft.^{3}).

[b] Number on left side of bar indicates number of colonies identified from total, which is the number on the right side of the bar.

[c] Predominant genera: Brevibacterium and Corynebacterium.

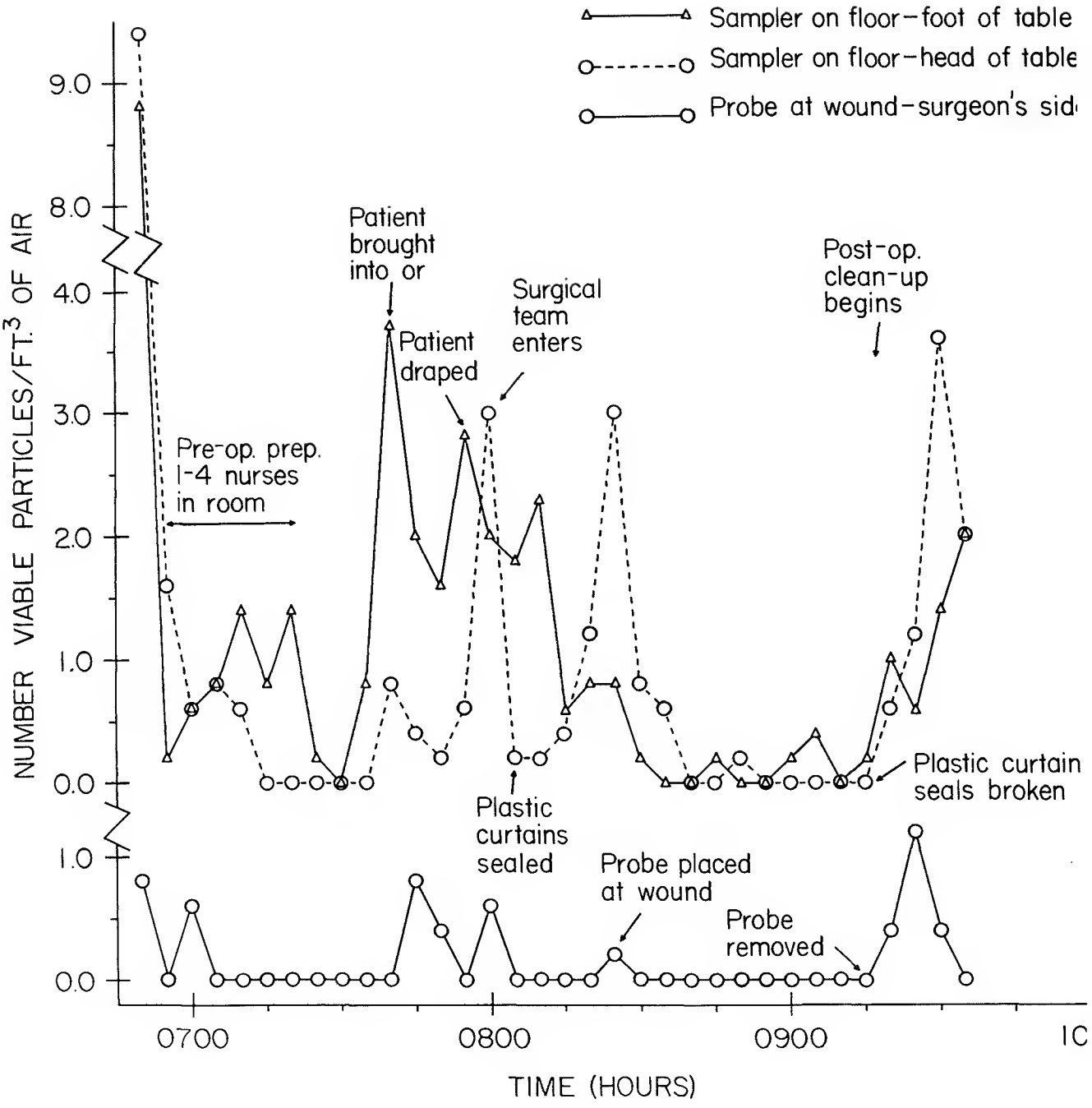

Figure 5. Air Sampling Studies Conducted in the Laminar Airflow Surgery During a Pleural Biopsy on the Right.

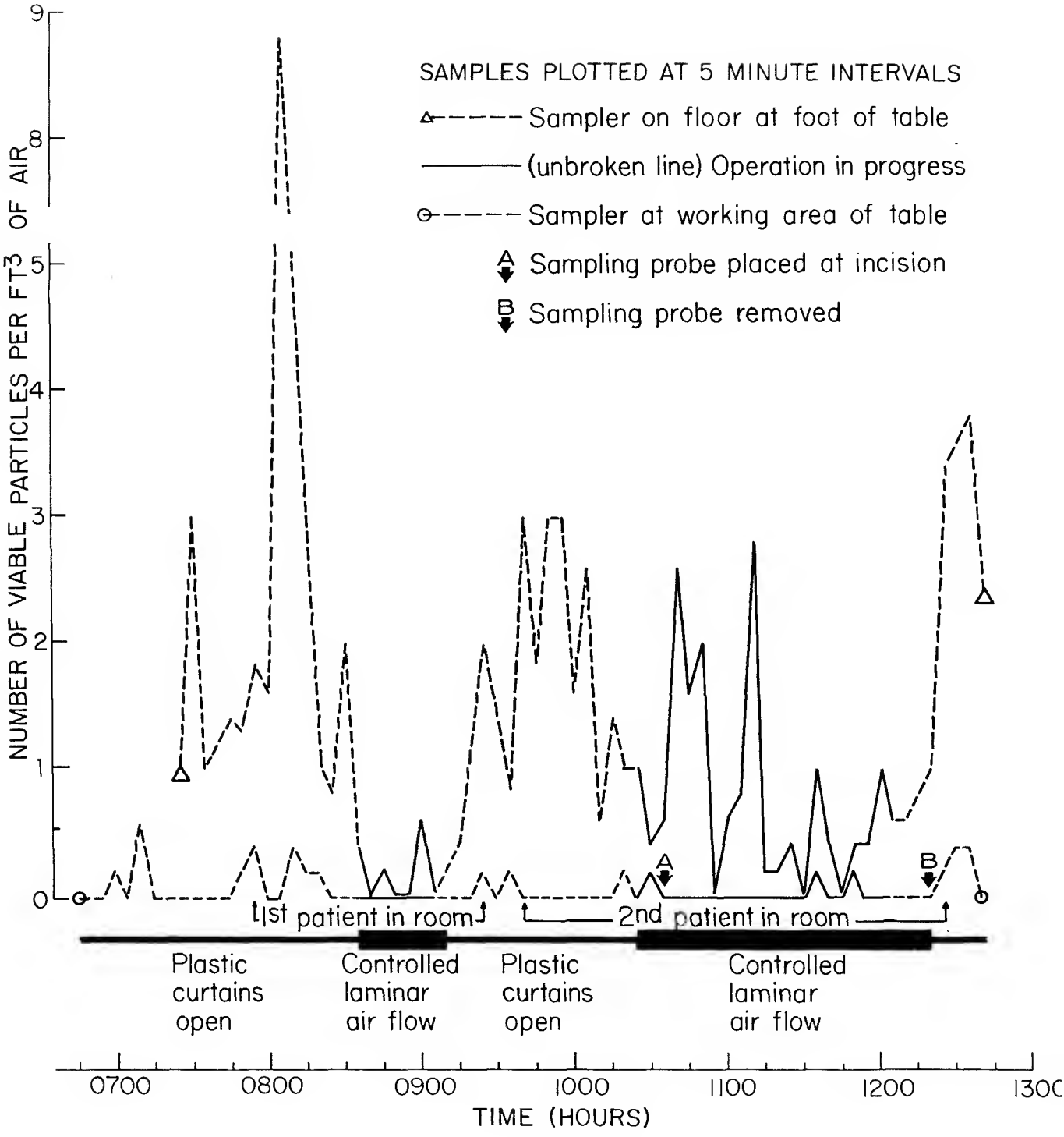

Figure 6. Air Sampling Studies Conducted in the Laminar Airflow Surgery During Removal of Spurs and a Spinal Fusion.

Table 2

Types of Microorganisms Recovered from the Air During Pleural Biopsy on the Right in the Vertical Laminar Airflow Operating Room

Type of Microorganisms	Percent of Microorganisms			
	Site No. 1, Floor Foot of OR table[a]	Site No. 2, Probe at surgeon's side of OR table	Site No. 3, Floor head of OR table	Site No. 4, Probe at Assistant's Side of OR table
	(204/206)[b]	(27/27)	(145/153)	(19/21)
Staphylococcus spp.				
Coagulase +	0.9	0.0	0.6	0.0
Coagulase -	42.9	29.6	32.5	42.1
Micrococcus spp.	26.9	59.2	47.5	47.4
Streptococcus spp.	2.9	0.0	2.7	0.0
Bacillus spp.	1.4	0.0	0.0	0.0
Miscellaneous Gram-positive rods[c]	16.7	11.2	10.6	10.5
Gram-negative rods	3.9	0.0	4.1	0.0
Molds	4.4	0.0	2.0	0.0

[a] Volume of air sampled: Site No. 1, (164 ft.^{3}); site No. 2, (169 ft.^{3}); site No. 3, (169 ft.^{3}); site No. 4, (165 ft.^{3}).

[b] Number on left side of bar indicates number of colonies identified from total, which is the number on the right side of the bar.

[c] Predominant genera: Brevibacterium and Corynebacterium.

Table 3

Types of Microorganisms Recovered from the Air During Spur Removal and Spinal Fusion in the Vertical Laminar Airflow Operating Room

Type of Microorganisms	Percent of Microorganisms			
	Site No. 1, Floor Foot of OR table[a]	Site No. 2, Probe at surgeon's side of OR table	Site No. 3, Floor head of OR table	Site No. 4, Probe at Assistant's Side of OR table
	(338/392)[b]	(21/25)	(276/292)	(39/39)
Staphylococcus spp.				
Coagulase +	1.2	0.0	1.0	0.0
Coagulase -	25.4	23.9	24.3	37.9
Micrococcus spp.	42.9	57.2	44.9	43.2
Streptococcus spp.	3.6	4.7	2.5	0.0
Bacillus spp.	2.7	0.0	2.2	0.0
Miscellaneous Gram-positive rods[c]	14.5	14.2	18.1	18.9
Gram-negative rods	5.0	0.0	2.3	0.0
Molds	4.7	0.0	4.7	0.0

(a) Volume of air sampled: Site No. 1, (303 ft.^{3}); site No. 2, (355 ft.^{3}); site No. 3, (355 ft.^{3}); site No. 4, (356 ft.^{3}).

(b) Number on left side of bar indicates the number of colonies identified from total, which is the number on the right side of the bar.

(c) Predominant genera: Brevibacterium and Corynebacterium.

removal and spinal fusion procedures. Again, as in table one, the predominant percentage of microorganisms (89-93%, pleural biopsy; 86-97%, orthopedic procedures) were those commonly associated with humans.

Figure seven contains the results of air sampling studies done in a conventional surgical theater (OR No. 2) during a left inguinal herniorraphy. As seen in this figure the number of airborne viable particles fluctuated throughout the entire surgical procedure at both sampling sites; i.e., on the floor at the foot of the OR table and at the wound site. The number of airborne viable particles at the wound site varied in the same general trend as did those recovered from the floor. Also, the number of airborne viable particles per cubic foot of air at the wound site were considerably higher (1.0-to-2.5) than the number recovered at the wound site (0.0-to-0.2) in the vertical laminar airflow surgery.

Table four contains the qualitative results of the types of microorganisms recovered during the left inguinal herniorraphy procedure in OR No. 2. From this table it can be seen that the contamination at the wound site is very similar to that recovered from the floor. It appears that the microbial contamination within the intramural environment of a conventional surgery is similar in kind and about the same in numbers throughout the room including that at the wound site; whereas the level of airborne viable contamination within a vertical laminar airflow is low and extremely low at the incision.

The present report describes a quantitative and qualitative study of the microbial contamination in a vertical laminar airflow surgical theater. Sampling sites were selected to provide a worst case situation, i.e., downstream on the floor, under the table where maximum turbulence of air might be expected. Foot movement by the surgical teams might tend to stir up microbial contamination on the floor and, therefore, provide for recirculation or accumulation of

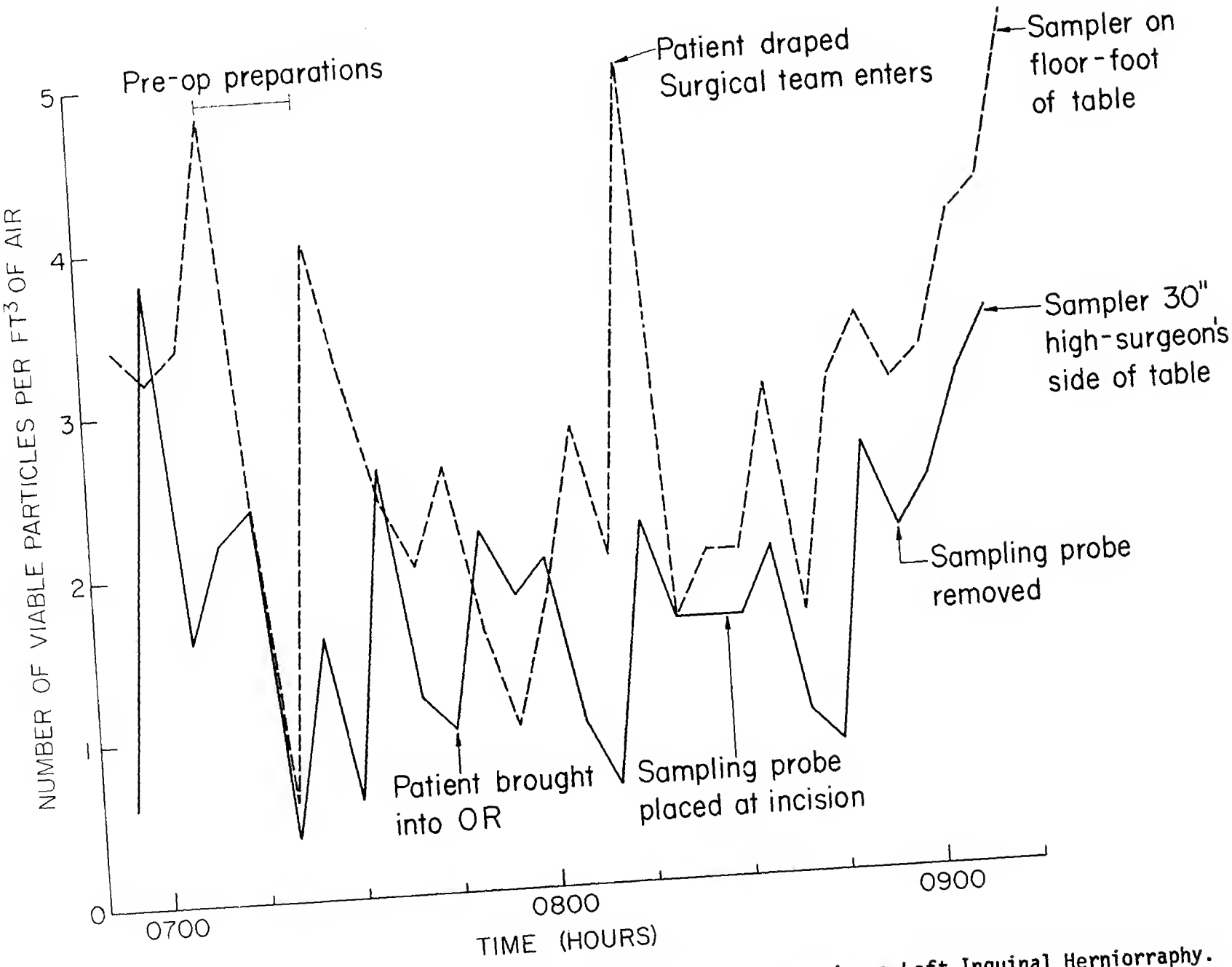

Figure 7. Air Sampling Studies Conducted in a Conventional Surgery During a Left Inguinal Herniorraphy.

Table 4

Types of Microorganisms Recovered from the Air During a Left Inguinal Herniorrhaphy in a Conventional Operating Room

Type of Microorganism	Percent of Microorganisms	
	Site No. 1, Floor-foot of OR table[a]	Site No. 2, Probe at Surgeon's side of OR table
	(415/449)[b]	(197/203)
Staphylococcus spp.		
Coagulase +	1.9	0.5
Coagulase -	32.7	36.5
Micrococcus spp.	25.5	31.9
Streptococcus spp.	5.5	3.6
Bacillus spp.	4.1	1.5
Miscellaneous Gram-positive rods[c]	19.5	19.8
Gram-negative rods	7.2	5.2
Molds	3.6	1.0

(a) Volume of air sampled: Site No. 1, (145 ft.^{3}); Site No. 2, (125 ft.^{3})

(b) Number on the left side of the bar indicates number of colonies identified from total, which is the number on the right side of the bar.

(c) Predominant genera: Brevibacterium and Corynebacterium

microbial contamination in these turbulent areas. However, from the data collected (Figures 4-6) accumulation of microbial contamination did not appear to occur in these turbulent areas. The other sampling area of interest was the wound site. Air samples were collected directly at the incision by means of sterile probes. At this sampling site, the number of viable particles recovered per $ft.^3$ of air was extremely low (Figures 4-6).

It is realized that some particle impingement may have occurred along the surgical tubing leading to the slit of the Reyniers samplers. However, preliminary studies using a Reyniers sampler with the slit orifice open and a Reyniers sampler containing a probe as shown in figure three did not result in a significant loss of viable particle collection with the sampler using the probe.

Some 1200 cubic feet of air were collected at the floor sites during four operations in the laminar flow surgery and a total of 1192 microorganisms were recovered of which 1103 (92.5 per cent) were subsequently identified. The largest percentage of microorganisms from the floor sites were Gram-positive cocci and Gram-positive nonsporeforming rods with considerably lower numbers of Gram-negative rods, Bacillus spp. and molds.

At the wound site during the same four operations some 1150 cubic feet of air were sampled and a total of 114 colonies were recovered of which 108 (94.7 per cent) were subsequently identified. The predominant species recovered at the incision were Gram-positive cocci and Gram-positive nonsporeforming rods only.

Sampling studies done in the conventional surgery showed the level of airborne viable particles to be higher than in the laminar flow surgery, both within the room and at the wound site. Contamination levels at the wound site generally followed the rise and fall trends noticed within the room. Essen-

tially the same types and percentages of all species found in samples collected at the floor level also were found at the wound site (Table four).

No known experimental evidence supports the contention that even though the number of viable particles in a laminar airflow stream are low (less than 0.2 viable particles per cubic foot of air), the wound site may be exposed to an increased number of viable particles due to the large volume of air passing over this area. In fact, the study reported by Whitcomb, et.al.[23], demonstrated that airborne particle impingement did not occur on agar settling plates and that the viable particles in airborne suspension moved out of the room as the laminar airflow stream was exhausted from the room. Furthermore, the viable particles in airborne suspension in a laminar airflow room only make a single pass through the room. In a conventional surgery such particles may be recirculated and have several opportunities to fall into the wound site.

Finally, it must be remembered that air samples collected in a laminar airflow room are only approximate and represent very small samples of segments of the moving air stream. Thus, it was felt particularly important to place two sampling probes at the wound site.

Presently it is not possible to predict nor comment on the post-operative infection rate occurring in either room. The post-operative infection rate in the conventional surgery is very low (ca. 1.0- to -1.5 per cent) and that in the laminar flow surgery is also very low (ca. 1.0- to -1.5 per cent). Statistical estimates have predicted that it will require comparisons of thousands of cases in each room before significant differences in the rate of post-operative infections can or cannot be detected in the two surgeries. However, it appears to us that the level of airborne viable contamination is extremely low in the laminar flow surgery and the fewer the contaminating microorganisms, generally, the fewer the chances for infection via the airborne

route. Of course, those infections resulting from direct contact cannot be expected to be prevented by using laminar airflow. However, the use of laminar airflow in the surgical theater may lend more light to the role played by airborne microbial contamination in post-surgical infections.

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